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Photo-exposure affects subsequent peat litter decomposition

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ABSTRACT

Exposure to sunshine is known to play a role in litter decomposition in some semi-arid areas. The aim of this study was to find out if it also plays a role in higher latitude environments in peat litter decomposition and could contribute to an explanation to the patchy nature of peat litter decomposition.

Peat litter from 5 microenvironments (top of slope, bottom of slope, ridge, ryam and hollow) and put out and exposed to the sun or shaded over a summer in Western Siberia, 26 km west of the town of Khanty-Mansiysk. Afterwards the peat litter was incubated in the laboratory - at field capacity or submerged in peat water - and CO_2 and methane emission measured. Chemical composition of exposed and control peat litter was also investigated using stepwise extraction.

The results indicate that exposure to sunlight does increase subsequent decomposition rate in most peat litters when incubated at field capacity, but the difference between the treatments levelled off at the end of the 2 weeks incubation in most peat litter types. The total extra carbon loss was calculated to be up to about 2 mg C m^{-2} over a season. When incubated submerged previous photo-exposure had less effect on CO_2 evolution then when incubated at field capacity. No methane emission was recorded in any treatment. Some differences in chemical composition between exposed and shaded peat litters were found that could help explain the differences in subsequent decomposition rate. The results indicate that photodegradation could play a role in peat litter decomposition at higher latitudes when peat is disturbed and exposed to sunshine. However, the effect of photo-exposure in these areas is much smaller than observed in semi-arid areas at lower latitudes.

1. Introduction

Several recent studies have indicated that photodegradation, enhancement of decomposition rate caused by exposure to light, may play an important role in plant residue and soil organic matter decomposition (Almagro et al., 2016; Austin and Vivanco, 2006, Day et al., 2007; Foereid et al., 2010; Gaxiola and Armesto, 2015; Gliksman et al., 2016; Mayer et al., 2012; Parton et al., 2007). Photo-exposure leads to increased emission of a number of carbon containing gases, including the potent greenhouse gas CH_4 (Lee et al., 2012). This could be explained if the effect of photo-exposure is to break or weaken long carbon chains (Davidson, 1996). There is evidence that particularly lignin, the plant substance most resistant to microbial decay, is affected by photo-exposure (Austin and Ballare, 2010; Lin et al., 2015). Photo-exposure may therefore interact with or prime plant litter for, microbial degradation (Almagro et al., 2016; Foereid et al., 2010; Gliksman et al., 2016; Wang et al., 2015).

Peatlands cover about 4 million km^2 globally (Joosten and Clarke, 2002). A large proportion of the planet's carbon stores are in the soil, and a disproportionally large percentage of this is found in northern latitude peats (Batjes, 1996; IPCC, 2007; Kremenetski et al., 2003; Page and Baird, 2016). However, surprisingly little is known about the controls of peat litter decomposition in natural and semi-natural ecosystems. Decomposition in peat litter appears to be patchy with a large portion of the peat litter seemingly inactive at any one time, but with hot-spots of microbial activity (Fenner et al., 2011). The difference between active and inactive patches has been difficult to understand. Many peatlands are currently disturbed by drainage, harvesting, cultivation or fires (Anderson et al., 2017; Page and Baird, 2016; Spiers, 1999). Many of these disturbances increase decomposition rate by lowing water table, but they could also leave more peat litter exposed.

Previous studies on terrestrial photodegradation have mostly focused on tropical semi-arid areas (e.g. Austin and Vivanco, 2006; Day et al., 2007; Gaxiola and Armesto, 2015; Pancotto et al., 2005; Vanderbilt et al., 2008) but there is potentially enough radiation in the summer also at higher latitudes on surfaces free of vegetation or with low vegetation cover to have an effect. Rutledge et al. (2010) showed that photodegradation plays a role for carbon fluxes in a de-vegetated

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peatland in New Zealand. A simulation of potential photodegradation world-wide showed a relatively large potential in some high latitude areas, due to low vegetation cover (Foereid et al., 2011). Photodegradation could be a factor in explaining the patchy nature of peat litter decomposition, and priming for microbial degradation could take place in peat litter as well. Photodegradation has been shown to play a role in decomposition in arctic waters, and to interact with microbial degradation (Cory et al., 2013). It is possible that exposure to sunlight in some exposed areas of the peat primes the peat litter there for microbial activity, and therefore explains the patchy nature of peat litter decomposition. Increased exposure to sunshine in degraded or eroded peatlands may also exacerbate the impact on carbon loss rates.

To answer the questions how large a role photodegradation could play in carbon cycling and greenhouse gas emissions in boreal peatlands and if the effect is different if the peatland is also drained and therefore exposed, we conducted an experiment. We hypothesized that exposure to sunlight would increase subsequent decomposition rate and that sun exposure could have a different effect on peat that was also drained. We also investigated if the changes induced by sun exposure could be picked up by standard chemical analyses, and if this could be used to predict subsequent decomposition rate.

2. Materials and methods

2.1. Study site

The study area was located at the left bank of the Irtysh River near the confluence with the Ob River in the Middle taiga zone of Western Siberia (60°54′N, 68°42′E), 26 km west of the town of Khanty-Mansiysk near the Field Station Mukhrino of Yugra State University. Vegetation outside the wetland is mainly boreal forest. The site is within the subarctic climate zone, with mean annual temperature − 1.3 °C and mean annual precipitation 553 mm. Because of the extreme continental climate, the short summer can be quite warm with mean temperature in July 17.1 °C. Based on data from NASA, monthly averaged insolation incident on a horizontal surface (kWhm^{-2} day^{-1}) were 5.17 in May, 5.79 in June, 5.64 in July and 3.87 in August (https://eosweb.larc.nasa.gov/sse/). The main mire type of the site is raised bogs covered by Pine-dwarf shrubs (*Ledum palustre*)-Sphagnum vegetation, "ryam" characterized by stunted pine trees (0.5–4 m high), and extensive ridge-hollow complexes, consisting of bog ridges and poor fen hollows. The soil is peaty and acidic (pH range 3.10–4.13, C/N 14–38, Table 1). The vegetation in "ryams" and on ridges is dominated by Ericaceous dwarf shrubs (*Ledum palustre*, *Chamaedaphne calyculata*, *Andromeda polifolia*) and in waterlogged hollows by *Eriophorum vaginatum* and *Carex limosa* as well as a few other species (e.g. *Scheuchzeria palustris*, *Rhynchospora alba*, *Oxycoccus* ssp., *Drosera* spp.). The ground layer is dominated by *Sphagnum* species, distributed following a moisture gradient with *Sphagnum fuscum* on hummocks and *Sphagnum balticum*, *S. jensenii*, *S. majus*, *S. lindbergii*, *S. papillosum* in hollows and sphagnum lawns. The fauna includes many species typical for the peatland and extensive river floodplains near the station and of the relatively dry mixed forests between the peatlands and the floodplains.

2.2. Sampling and characterization of microsites/peat litter types

Peat litter was sampled from 5 microsites within the peatland (the top and bottom of an eroded slope, a ridge, a ryam, and a hollow) in late May (10–30 cm depth). Details on each site/peat litter type are given in Table 1. Water table at each site was determined in the field in July. Peat litter samples (4 replicates) were air dried and compared. pH (H_2O, 1:20 w:w) was measured and water holding capacity determined. Samples were then composited for other analyses. A subsample was ground using a blender. Elemental composition was measured on an elemental analyzer EuroVector EA-3000 (Italy) on the ground sample in triplicate. Standard reactor (quartz reactor filled by chromium oxide and copper reduced) and chromatograph column (GC column SS-2m) for CHNS-analysis in helium flow were used. Calibration was performed using Acetanilide (C = 71.09%, H = 6.71%, N = 10.36%). A subsample of composited samples was taken out for quantitative microscopic analysis. Samples were sieved (0.25 mm) under flowing water. Plant remains were identified by comparing with stored standard samples of peat forming plant species (Kats et al., 1977) and the percentage of each species in the peat litter sample were recorded. The peat litter was classified into peat types based on the dominant species.

2.3. Photo-exposure

Bags were prepared with cotton material on one side for heat exchange, and UV-transparent Alcal plastic film (same as used by Austin and Vivanco, 2006) on the other. The dimension was 0.29 m × 0.19 m. Control bags also had a layer of black plastic between the sample and the Alcal plastic. In this way, other climatic factors would be as similar as possible in control and sun exposed bags. However, it is almost impossible to give a radiation treatment without the risk of changing temperature, and we cannot rule out that there could have been a small but consistent difference also in temperature between exposed and control bags. The collected peat litter was dried and weighed and put in the bag, all peat litter samples (4 replicates) split into two to have both exposed and control from each sample. Peat litter was spread as evenly as possible in the bag, to give a layer of about 50 mm thickness. All bags were put out and fastened on an exposed wooden platting on flat ground with little shading vegetation around in the peatland. The bags were put out on 24th of May and collected on of 21st of August 2013.

2.4. Incubation and gas sampling

About 5 g of dry peat litter from each bag (sun exposed and shaded)

Table 1
Characteristics of sampling site/peat litter types within the peatland. Standard errors are in brackets.

	Top of slope	Bottom of slope	Ridge	Ryam	Hollow
Peat type	*Scheuchzeria* peat		*Sphagnum* (*fuscum*) peat		Sedge-*Sphagnum* peat
Peat composition (% of all plant remains)	*Scheuchzeria*, 55 Shrubs, 20 *E. russeolum*, 10 *Sph. Papillosum*, 10 *C. limosa*, 5 *Polytrichum commune*, trace	*Scheuchzeria*, 90 *E. russeolum*, 5 Shrubs, 5	*Sph. Fuscum*, 70 *Sph. Capillifolium*, 20 *Polytrichum strictum*, 5 Shrubs, 5	*Sph. Fuscum*, 100 Shrubs, trace	*Sph. Papillosum*, 45 *C. limosa*, 30 *E. russeolum*, 15 *Sph. Majus*, 5 *Sph. Jensenii*, 5 *Sph. balticum*, trace
Water table (cm)	–	–	37	35	8
C (%)	53.6 (1.6)	53.8 (0.13)	44.1 (1.8)	49.0 (3.07)	50.6 (0.75)
N (%)	3.73 (0.11)	3.20 (0.05)	1.16 (0.03)	1.50 (0.20)	2.76 (0.05)
C/N	14.4 (0.5)	16.8 (0.4)	38.1 (4.3)	33.3 (4.9)	18.4 (0.9)
pH	4.03 (0.07)	3.64 (0.05)	3.23 (0.03)	3.10 (0.03)	4.13 (0.12)
WHC	0.95	2.69	3.42	5.26	4.96